NOAA TECHNICAL MEMORANDUM NMFS SEFC-74

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
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Malcolm Baldrige, Secretary
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James P. Walsh, Administrator
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Terry L. Leitzell, Assistant Administrator for Fisheries

INTRODUCTION

Cadmium is a ubiquitous environmental pollutant with toxic properties that gives cause for concern over its potential contamination of and accumulation in the nation's food supply. Major pollution sources of cadmium are alkali storage battery manufacturing plants (1), electroplating facilities (2), and smelting operations (3). Cadmium poisoning, when it occurs, is usually regarded as an occupational problem. Numerous symptoms of cadmiosis have been reported among industrial workers (3-6), but anemia (7) and renal tubular dysfunction (8) appear to be the most commonly described symptoms of chronic exposure to relatively high levels of cadmium. The toxicology of cadmium and its inorganic compounds have been well documented and reviewed (3, 6). Whereas the U.S. general population is exposed to low concentrations of cadmium, primarily from dietary sources, no evidence of long term (chronic) ill effects attributable to such sources can be found. Nevertheless, there is global awareness of the subtle toxic effects of this element and the need to minimize its contribution to the human diet.

The joint committee of the Food and Agriculture Organization of the United Nations and the World Health Organization (FAO/WHO) reported a "provisional tolerable weekly intake" for cadmium (for a 60 kg man) of 400-500 ug (9). The U.S. Food and Drug Administration (FDA) estimated the mean dietary intake of cadmium in the United States in 1974 from all food sources to be 72 ug/day (10), a level that closely approximates the FAO/WHO guideline. The published FDA data include the contribution of cadmium from seafoods as part of the meat, fish and poultry food category, not broken out separately. It has been estimated, however, that a typical single serving of oysters contributes 50 ug cadmium to the diet (11). This estimate may be conservative, in view of National Marine Fisheries Service (NMFS) data (12) indicating a mean cadmium content of 0.96 ug/g for 151 eastern oyster (Crassostrea virginica) samples obtained from typical harvesting locations. Other bivalves also were found to have similar levels of cadmium in their edible parts (12). Re-evaluation of the FDA data on daily intake of various food commodities, including specific data on cadmium levels in bivalves, might suggest that certain segments of the public (e.g., persons eating large numbers of oysters) may significantly exceed provisional tolerable intake levels of cadmium as defined by FAO/WHO.

Purpose of Report

The purpose of this report is to present the results of a NMFS study to determine the gross dietary intake of cadmium (i.e., without regard to its bioavailability or ultimate biological actions) by U.S. consumers, attributable only to seafoods, and to provide an estimate of the percentage of the population having a predetermined probability of exceeding a prescribed intake of cadmium from seafoods (subsequently referred to herein simply as "risk"). A computer simulation model was developed to use available NMFS data on cadmium content of fish and shellfish and available data on seafood consumption in the United States to determine the statistical chances of consumers exceeding a daily intake of cadmium from seafoods of 72 ug/70 kg body weight, defined herein as acceptable daily intake (ADI). It is emphasized that no action (tolerance) level has been established for cadmium in seafoods by the FDA, and that comparisons are made only to the FAO/WHO criterion for total dietary intake. A large proportion of dietary cadmium is in fact supplied from foods other than seafoods, a point that is enlarged upon later in this paper.

Two major assumptions have been made in presenting this work. First, that the sample of seafood consumers used for input to the computer model (approximately 24,000 individuals, see below) may be extrapolated to represent the U.S. general population in terms of kinds, amounts and frequency of seafoods consumed. Second, that the mean levels of cadmium (taken from an earlier NMFS trace element survey, see below) assigned to the various species of fish and shellfish consumed by the sample population, accurately reflect cadmium levels typically present in seafoods.

Cadmium Data Base

Each record of the cadmium data file (summary, Table 1; see also ref.12), contains information by seafood species name, when the specimen was caught (month and year), where it was caught (latitude and longitude), its weight, and the level of cadmium in the edible flesh in ug/g. In all, over 8,000 samples, representing approximately 200 species of finfishes, mollusca and crustacea from sites around the coastal United States, including Alaska and Hawaii, are represented in this data file. However, some of the historical information was not always recorded by the collectors. Therefore, appropriate data adjustments were made to provide as much information as possible. For example, unweighed samples were assigned the average weight of all specimens of that species on the file. Replicated contaminant measurements were represented by using an average value in subsequent calculations. Cadmium values reported as nondetectable were replaced by random entries from a triangular distribution between zero and the detection limit in order to eliminate bias, as was done in an earlier application of the simulation model to dietary intake of mercury (13).

Each species or subspecies category of the simulation model described in this report is represented by a unique lognormal probability distribution function for the contaminant. However, consumers usually do not differentiate between two subcategories of the same species (e.g., northern lobster, inshore, and northern lobster, offshore). A combination of such subcategories, therefore, was built into the model to accommodate broad market categories. The proportionality factors were determined from the average weight and total commercial landings of each species during the period of the seafood consumption survey used as the basis for this and the mercury report (13), as indicated in Fishery Statistics of the United States for 1973 (14) or from industry data.

When the name of the species eaten at a meal was not reported, a "Not Reported" category for a representative mix of species was used (See ref. 13, p.5, for details). Similarly, when the species was reported only as shellfish, an "Other Shellfish" species category was developed from proportionate consumption information derived from the consumption survey (13). When cadmium values were lacking for a particular species reported as consumed, suitable substitutions used previously (13) were employed. The mixtures or substitutions used in this report are provided in Table 2.

Consumption Data Base

The data placed in the consumption file were collected by NPD Research, Inc., Chicago, Illinois, during the period 1973-1974 (13). Information was obtained from 25,947 consumers of whom 24,652 had recorded eating seafood of some kind. The consumers questioned in this survey represented all major demographic groups.

Each family kept a diary for a one-month period, during which time each seafood meal was recorded by a family member. In addition, half of the panelists kept the diary for one year (September 1973-August 1974). Age, sex, and geographic location were recorded for most panelists. Age and sex were sometimes found to be missing in the completed diaries. In those cases a sex of "Not Recorded" and default age of 99 were used to account for the errant panelists. One hundred incomplete records were corrected by an ad hoc committee, representing the Environmental Protection Agency, the U.S. Department of Agriculture, the Tuna Research Foundation, the National Fisheries Institute, and NMFS, by referring back to the original 100 diaries (13). An important piece of information that was missing from every person's diary was their body weight. That information was needed to calculate each personal ADI. Table 3 presents the assumed average weight for the seven sex/age groups utilized by the program.

Each seafood meal record from the NPD survey contained the species, total amount of seafood available (product form), identify of what each family member had eaten, and number of servings eaten by each person. However, the actual serving size information needed to determine the actual consumption of seafood was not recorded. Average serving sizes by age groups used to provide such information is presented in Table 4. Species consumed by the panelists in declining order of use are identified in Table 5. The reader should review the mercury report (13) to obtain more details concerning the consumption survey.

HISTORY AND DEVELOPMENT OF CONSUMER-RISK MODEL

General Development of a Simulation Model

Answers to large, complex questions often require great investments in time and money, which may not be available. In such situations, one can often use a mathematical tool, the simulation model, in order to better understand the system under investigation, as well as to test proposed solutions to system problems. Modules, each representing an event of the system, are constructed and linked together to study the behavior of events and their interrelationships, as portrayed by appropriate probability distribution functions.

After the initial model has been constructed, test data sets are entered into the model to determine how realistically it portrays the true situation. Several iterations of the model may be required before it is considered validated, i.e. before the model is considered to approximate the real system. Events are often modeled by using probability distribution functions. Data represented by these distributions are randomly generated or selected from a large data base. Because the model is using random data points, the results of a particular computer run cannot be assumed to precisely reflect the true situation. Thus, depending upon the inherent variability of the system under study, several runs must be made in order to obtain an average value or result that closely approximates the true situation.

Background of Consumer-Risk Model

In 1978, NMFS submitted to the FDA the results of a contracted study (13) to determine the intake of mercury by U.S. consumers of fishery products after first developing a computer simulation model which incorporated NMFS data on mercury levels in fish and shellfish with data on seafood consumption. The results were discussed in terms of the established action level for mercury (0.5 ug/g at that time). The report also permitted an evaluation of alternative action levels for consumer safety considerations. Subsequently, the mercury model was modified so that it could be used in broader applications, particularly in regard to dietary contaminant questions. A user guide was also developed to assist in such use. The reader is referred to the user guide (15) for a detailed description of the operation of the consumer-risk model employed in this study. However, major points of the model will be briefly summarized here in order to assist in interpreting the results derived from use of the model.

Overview of the Consumer-Risk Model

The consumer-risk model employs an interactive auxiliary program that easily allows an informed user to run the primary program as well as to vary input covering a multitude of situations. The interactive program draws upon data in two modules to assess the potential impact of any contaminant situation. The first module, labelled the species module, assesses contaminant levels within each kind of seafood eaten by consumers. The second module, labelled the consumer module, actually "feeds" seafood products to consumers. The user models a particular situation by varying input parameters.

The model has a number of features which make it quite realistic. For example, seafood products are harvested over a wide range of locations throughout the year. Moreover, fish come in a variety of sizes and, depending upon the contaminant and species involved, it may be necessary to assign different contaminant values according to size (age) of the fish or the location from which the fish are harvested. The cadmium data base employed in this report consists of information derived from fish collected from scientific surveys of the marine resource and not from commercial sources. The size and harvest location of seafood products are well known, however, and there is no reason to suspect that cadmium levels derived from field surveys should be significantly different from those found in fish obtained from the market-place. Thus, because size and location information is generally known, it is quite easy to simulate commercial catch and distribution patterns, using certain capabilities of the model. For example, if it is determined that 80 percent of flounder consumed by the public weighs 500 g or less, and 20 percent weighs over 500 g, the model applies a weight option to divide flounder into these two categories. Further, if 65 percent of the flounder were taken from the North Atlantic and 35 percent from the South Atlantic, a location option would be applied. Given this information, the model then examines the contaminant data base, divides all available flounder data into the four groups that have been identified and calculates the mean and standard deviation of the contaminant levels specific to those groups. The way in which these statistical parameters are derived is described briefly below.

In his earlier development of the model for mercury, Krutchkoff (13) examined the NMFS contaminant data base (12) to determine the best fit for mercury. This was subsequently done for cadmium values as well. Both data sets were determined to be lognormally distributed. A computer program was utilized to fit and plot the data. As an example, the cumulative distribution function of cadmium values in oysters is shown in Figure 1. Once the cumulative probability distribution function is known for the contaminant and seafood species under investigation, a mean and standard deviation can be readily determined using standard statistical procedures.

Two other parameters used in the operation of the model and relevant to estimating the probability of exceeding any stated dietary intake of a contaminant, are the action level (AL) of the contaminant and the corresponding law enforcement level (EL). An action level, when required, is set on the basis of an ADI which, during the entire lifetime of a consumer, appears to be without appreciable risk to human health. The concentration of a contaminant in a given food product must be below the action level for that food to be considered acceptable for human consumption. As stated earlier, no action level for cadmium in seafoods has been promulgated by the FDA. Any action level may be assumed by the simulation model, however, without regard to a regulatory ADI applicable to seafoods. Three such hypothetical "action levels" were introduced for modeling purposes, as discussed in subsequent sections of this report. The law enforcement level is a measure of the effectiveness of withholding from the consumer foods (in this case, seafoods) which contain contaminant (in the case, cadmium) levels higher than the stated action level. The model allows this parameter to be varied arbitrarily between zero and 100 percent. In this report, a 75 or 100 percent level of law enforcement was assumed, thus allowing the model to provide a high degree of "compliance" with each of the three arbitrary action levels selected.

RESULTS AND DISCUSSION

A typical computer output run based on the computer simulation model for cadmium is shown in Table 6. In this case only oyster eaters (1,241 people) were included. An action level of 2 ug/g and an enforcement level of 75 percent have been applied to the model. The percentage of this particular segment of the population exceeding its personal ADI was determined at different probability (risk) levels. The various sex and age groups were also delineated. For example, when all oyster eaters were included, 0.08 percent were found to exceed their personal ADI's, on the average, 5 percent of the time. Further, taking into account only female oyster eaters between the ages of 11 and 17 (48 people), none was found to exceed their personal ADI, at any probability level.

A series of such runs were generated[1/],taking into account all of the various consumer categories (all seafoods, all finfish, all shellfish, and oyster eaters) at three different hypothetical action levels

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[1/] Copies of output runs may be obtained from the Office of Data Processing & Statistics, SEFC, Charleston Laboratory.

(AL = 20, 2 and 1 ug/g) and two enforcement levels (EL = 100 and 75%). The action levels were selected arbitrarily to best illustrate the working of the model. It should be realized that the use of guidelines or action levels such as the 20, 2 or 1 ug/g assumes that exposure would in fact take place around one or the other of these levels. Such is usually not the case. Experience has shown that as a result of most, if not all action levels, residues and exposure tend to fall well below the action level. A default level of AL = 20 ug/g is sufficiently high to represent the situation in which, in practical terms, no regulatory control could be envisaged. The levels AL = 2 and 1 ug/g are low enough to exert an influence on the computed risk factors and are not atypical of cadmium concentrations found in some of the more heavily contaminated molluscs. Some of the more striking results emerging from this modeling exercise are discussed below.

The influence of changing the action level and/or enforcement level on computed risk is illustrated by the results summarized in Table 7. In this example it can be seen how the assumed enforcement level influences the percentage of the population with a 5 percent chance of exceeding its personal ADI for cadmium in seafood. When the hypothetical statutory level for cadmium in all shellfish is high, relative to concentrations generally encountered in this class of seafoods (i.e., AL = 20 ug/g, Table 7), and the enforcement level is 100 percent, 2 people in 10,000 are at a 5 percent risk of exceeding their recommended ADI. However, when the enforcement level is reduced to only 75 percent, 7 people in 10,000 have the same likelihood of risk. The implications of greatly reduced enforcement are clear, in terms of computed risk.

The model vindicates the application of the least restrictive regulatory action when a choice can be made without apparently compromising the safety of the consumer. An action level of either 2 or 1 ug/g for both shellfish and oysters results in the same percentage of the population at risk, at an enforcement level of either 100 or 75 percent (Table 7), suggesting that an action level of 2 ug/g would afford the same degree of protection as 1 ug/g at a constant level of enforcement. Finally, Table 7 illustrates that of the commercially important species examined in the model, only oysters make a significant contribution of cadmium to the diet, i.e., 48 persons out of 10,000 have a 5 percent chance of exceeding their personal ADI when, in practical terms, no action level is established.

The frequency of eating seafood meals and the mean cadmium level in the consumed fishery products are also found to influence the number of people computed to be at risk, as shown in Table 8. Doubling either factor results in a marked increased in the percent population in the 5 percent risk category. When the enforcement level is 100 percent, such an increase in either consumption or mean level have identical effects on the percentage at risk. At the lower (and more practical) enforcement level of 75 percent, however, increasing the consumption factor by two appears to place more people at risk than increasing the mean factor by the same degree. This result suggests it would be particularly important to better define the eating habits of the population with regard to oysters, and to monitor future increases in average cadmium levels for this major shellfish resource. Clearly, persons eating disproportionately large numbers of oysters as part of their regular diet are subject to an increased probability of exceeding any predetermined cadmium intake.

It can be seen from Table 9 that with an enforcement level of 75 percent and twice the consumption factor for oysters, there is only a slight benefit to be gained by imposing a 1 ug/g versus 2 ug/g action level. When the mean factor is doubled, however, there is no apparent benefit from imposing the lower action level. This result implies that even if oysters were to accumulate considerably higher levels of cadmium in the future, a 2 ug/g action level would continue to provide the same degree of protection to the consuming public. Only if the population ate significantly larger quantities of oysters might the lower action level of 1 ug/g help reduce the associated risk of ingesting cadmium.

Several other factors must influence any decisions regarding acceptable levels of cadmium in seafood products. Numerous constituents of the typical U.S. diet are known to influence the metabolism of cadmium in the human body (3, 16-18). Among these dietary factors, zinc, copper, iron, selenium and cysteine occur at elevated levels in fishery products. Fox et al. (19), for example, have determined the bioavailability to Japanese quail of cadmium derived from scallops and oysters to be respectively 62 percent and 38-48 percent that of cadmium chloride. Lagally et al. (20, 21) have also found that cadmium is retained in critical organs to a lesser extent when fed to rats as a contaminant in calico scallops rather than cadmium sulfate added to the animal diet. A substantial research effort is currently being funded by the NMFS to further evaluate the relative bioavailability and metabolism of cadmium present in oysters, using the mouse as a test animal. It is anticipated that this latter work will also further define the influence of dietary factors, including several of those listed above. Thus, a definitive assessment of potential chronic intake of cadmium attributable to consumption of seafoods must await the answers to several critical questions currently being addressed by researchers. Clearly, if cadmium from oysters were found to be significantly less available to consumers than the common inorganic additives used in metabolic studies (e.g., cadmium chloride), an even lower degree of risk would be implied, with positive implications for seafood eaters and the shellfish industry.

It is important to emphasize that a person who exceeds his/her personal ADI on any given day is not necessarily at any real risk to health. Cadmium is a cumulative poison which, at relatively low levels, may exhibit its toxic properties only after prolonged exposure of an individual to its presence. Therefore, the probability values generated by the model should be viewed only as an estimate of the potential exposure of the U.S. population to cadmium from seafoods. In the absence of established acceptable daily dietary intakes for cadmium from all food sources, including seafoods, and the lack of explicit information on other factors affecting toxicity, the results of this modeling cannot be extrapolated to provide a verifiable determination of health hazard.

The use of the model is restricted to consideration of dietary cadmium acquired from seafood when, in fact, the major contributors of cadmium to the total diet are cereals and grains, i.e., 23 percent of total dietary intake (22). Within the "market basket" survey of the FDA, the meats, fish and poultry food category accounted only for approximately 7 percent of the cadmium contribution to the total diet, evaluated over eight years of the program (23). This latter report also reevaluated earlier FDA data, adding analyses of specific commodities to the data of the "market basket" survey to obtain a new estimate of the average dietary intake based on the combined data. The more recent value is 57 ug/day, compared to the 35 ug/day overall from the eight years of the "market basket" survey, and approximates the tolerable limits for all sources recommended by the WHO/FAO (57-71 ug/day). If the contribution from seafood at the present time is indeed less than 7 percent (4 ug/day) of the total dietary cadmium, then doubling or tripling this value would appear to have a negligible effect on the potential health risk to the general population. There appears to be some conflict, however, between the data of NMFS and that of FDA with respect to the relative consumption of cadmium attributable to seafoods. Using this computer simulation model it would appear that approximately 10 percent of the population has a greater than 5 percent chance of consuming more than 4 ug/day cadmium from fishery products (Figure 2). Thus, if the sample population used by the model is truly representative of the general population, then the contribution to dietary cadmium from this food source cannot be ignored.

CONCLUSIONS

The results of this modeling are not intended for use as a basis for recommending an action level for cadmium in seafoods. Rather, they are presented to show the applicability of a computer simulation technique to provide estimates of consumer risk arising from dietary intake of this (or any other) contaminant. At the present time, the lack of an established ADI for cadmium in seafoods restricts the use of the model to generating "risk estimates" only in terms of exceeding the provisional FAO/WHO tolerance level. In this regard, more basic research is needed to evaluate the bioavailability and eventual toxicity of cadmium from seafoods relative to the toxic effects presently ascribed to forms of cadmium commonly used in metabolic studies. Furthermore, the total dietary intake of cadmium from foods other than seafoods will have to be better defined before the probability of exceeding an individual ADI can be determined. Finally, the eating habits of the U.S. population also should be better defined in regard to consumption patterns for specific seafoods, e.g., oysters. This information could be used to determine if specific segments of the population are exposed to a higher than normal dietary cadmium intake and thus fall in an increased risk category.

In conclusion, the model does effectively illustrate that if there is a significant contribution by seafoods to dietary intake of cadmium, it is most likely restricted to consumers of large amounts of molluscs (oysters). It also shows that the level of law enforcement would be a critical factor in any assessment of the utility of applying an action level to this seafood category. Although there does not appear to be a pressing need for large scale surveying of seafoods for cadmium contamination, it would be prudent to selectively monitor the shellfish resources to extend and improve the quality of this data base.

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LIST OF TABLES AND FIGURES

TABLE 1

Summary of Cadmium Values in NMFS Resource Survey[1/]

Species	No. of[2/] Samples	Average Weight (g)	Mean Cd Level (ug/g)	Locations[3/] Sampled
Abalone	20	902	1.17	C
Anchovies	80	23	.28	C, G
Bass, sea	55	35	.06	N, S
Bass, striped	117	4491	.06	C, N, W
Bluefish	74	1148	.05	G, N, S
Bonito	40	13659	.11	C
Butterfish	91	81	.08	N
Catfish (freshwater)	35	1480	.06	F, G, N
Catfish (marine)	81	754	.06	G
Clams	586	165	.24	K, N, S, W
Cod	134	1849	.05	N
Crab, king	49	N.A.	.17	K
Crab, other	261	321	.16	C, G, K, N, S, W
Croaker	92	332	.07	G, N, S
Dolphin	63	7254	.06	G, H, S
Drums	139	1787	.06	G, N, S
Flounders	1002	640	.06	C, G, N, S, W
Groupers	125	6309	.05	G, S
Haddock	89	1277	.05	N

See footnotes at end of Table 1.

TABLE 1 (continued)

Species	No. of Samples[2]	Average Weight (g)	Mean Cd Level (ug/g)	Locations Sampled
Hake	365	526	.05	C, N, W
Halibut 3	10	87111	.06	K
Halibut 2N	10	8947	.06	K
Halibut 2S	27	12415	.06	W
Herring	251	471	.08	K, N, W
Kingfish	20	116	.06	G, N
Lobster, northern (inshore)	132	1072	1.17	N
Lobster, northern (offshore)	57	1503	.18	N
Lobster, spiny	54	522	.10	C, G, S
Mackerel, Atlantic	112	393	.08	C, N
Mackerel, jack	14	2200	.08	C
Mackerel, king	87	3485	.05	G
Mackerel, king	20	4368	.08	S
Mackerel, Spanish	65	832	.05	G
Mackerel, Spanish	43	538	.08	S
Mullet	194	567	.06	G, H, S
Oysters	404	158	1.63	C, G, N, S, W
Perch (marine)	207	533	.07	C, N, S, W
Pollock	133	1893	.06	K, N, W
Pompano	60	584	.07	G, S
Rockfish	121	2686	.05	C, W
Sablefish	103	2510	.05	C, K, W

See footnotes at the end of Table 1.

TABLE 1 (continued)

Species	No. of Samples[2/]	Average Weight (g)	Mean Cd Level (ug/g)	Locations Sampled[3/]
Salmon	332	4539	.06	C, K, W
Scallops	137	124	.79	K, N, S
Scup	74	172	.06	N, S
Sharks	320	11629	.09	G, N, S, W
Shrimp	348	12	.09	C, G, K, N, S, W
Smelt	33	N.A.	.13	W
Snapper, red	49	4238	.05	G, S
Snapper, other	212	1711	.07	C, G, H, P, S
Snook	12	3797	.06	G
Spot	54	103	.06	N, S
Squid & Octopi	315	365	.37	C, H, N
Tilefish	60	5184	.06	G
Trout (freshwater)	8	3099	.06	W
Trout (marine)	190	687	.06	G, N, S
Tuna, skipjack	70	3413	.08	C, H, P
Tuna, yellowfin	90	22250	.08	C, H
Tuna, white meat	40	4740	.07	C, W
Other Finfish	115	3979	.07	C, N, W

1/ Hall et al, 1978, Ref. 12
2/ Most of the samples were obtained during 1971 (See Ref. 12)
3/ K = Alaska; W= Pacific Northwest; C= California; G= Gulf of Mexico; S = South Atlantic; N = North Atlantic; H = Hawaii (See Ref. 12)
N.A. = Not Available

TABLE 2

Species Substitution for Seafood Categories
Reported in the Consumption Survey

NOT REPORTED	
7.95%	BASS, SEA
2.30%	CLAMS
7.95%	COD
13.60%	FLOUNDERS
7.95%	HADDOCK
2.30%	HERRING
2.30%	OYSTERS
7.95%	POLLOCK
11.40%	SALMON
4.50%	SHRIMP
11.40%	TROUT (FRESHWATER)
7.55%	TUNA, LIGHT SKIPJACK
8.36%	TUNA, LIGHT YELLOWFIN
4.49%	TUNA, WHITEMEAT

BLUEGILLS	
100.00%	TROUT (FRESHWATER)

BUFFALOFISH	
100.00%	TROUT (FRESHWATER)

CARP	
100.00%	TROUT (FRESHWATER)

CRAPPIE	
100.00%	TROUT (FRESHWATER)

PERCH (FRESHWATER)	
100.00%	TROUT (FRESHWATER)

PIKE	
100.00%	TROUT (FRESHWATER)

SUNFISH	
100.00%	TROUT (FRESHWATER)

SWORDFISH	
100.00%	SWORDFISH

WHITEFISH	
100.00%	TROUT (FRESHWATER)

OTHER SHELLFISH	
0.20%	ABALONE
12.00%	CLAMS
0.60%	CRAB, KING
5.80%	CRAB, OTHER THAN KING
7.65%	LOBSTER, NORTHERN (INSHORE)
1.35%	LOBSTER, NORTHERN (OFFSHORE)
1.60%	LOBSTER, SPINY
7.80%	OYSTERS
63.00%	SHRIMP

BASS	
29.00%	BASS, SEA
71.00%	BASS, STRIPED

HALIBUT	
21.28%	HALIBUT 3
21.28%	HALIBUT 2N
57.44%	HALIBUT 2S

LOBSTER, NORTHERN	
85.00%	LOBSTER, NORTHERN (INSHORE)
15.00%	LOBSTER, NORTHERN (OFFSHORE)

MACKEREL, OTHER THAN JACK	
22.07%	MACKEREL, ATLANTIC
10.93%	MACKEREL, KING (GULF)
18.62%	MACKEREL, KING (OTHER)
31.93%	MACKEREL, SPANISH (GULF)
16.40%	MACKEREL, SPANISH (OTHER)

SNAPPER	
70.00%	SNAPPER, RED
30.00%	OTHER SNAPPER

TUNA, LIGHT	
47.44%	TUNA, LIGHT SKIPJACK
52.56%	TUNA, LIGHT YELLOWFIN

TABLE 3

Average Body Weights[1/]

Age Groups (yrs)	Males (kg)	Females (kg)
0-1	7	7
1-5	15	15
6-11	31	31
12-17	56	52
18-54	72	59
55+	74	64

1/ Information taken from USDA Handbook No. 11, Table 143, p. 279

TABLE 4

Average Serving Size for Seafood2/

Age Groups (yrs)	Males (g)	Females (g)
0-1	20	20
1-5	66	66
6-11	95	95
12-17	131	100
18-54	158	125
55-75	159	130
75+	180	139

2/ Information taken from USDA Handbook No. 11, Table 10, p. 40-41.

TABLE 5

Seafood Categories and Number of Panelists Using Each Category

Seafood Category	Panelists	Seafood Category	Panelists
TUNA, LIGHT	16817	CRAPPIE	228
SHRIMP	5808	TROUT (MARINE)	220
NOT REPORTED	5117	BONITO	148
FLOUNDERS	3327	CRAB, KING	130
PERCH (MARINE)	2519	MULLET	97
SALMON	2454	SPOT	91
CLAMS	2242	CROAKER	76
OTHER FINFISH	1503	ANCHOVIES	75
COD	1492	ROCKFISH	75
POLLOCK	1466	CATFISH (MARINE)	70
HADDOCK	1441	GROUPERS	68
HERRING	1251	CARP	64
OYSTERS	1241	BUFFALOFISH	60
CRAB, OTHER THAN KING	1168	SUNFISH	60
TROUT (FRESHWATER)	970	DRUMS	58
CATFISH (FRESHWATER)	876	SCUP	55
BASS	826	OTHER SHELLFISH	54
LOBSTER, NORTHERN	675	ABALONE	48
MACKEREL, OTHER THAN JACK	616	SQUID AND OCTOPI	45
HALIBUT	574	SWORDFISH	41
SCALLOPS	526	BUTTERFISH	39
WHITEFISH	492	DOLPHIN	34
SNAPPER	490	TUNA, WHITE MEAT	22
HAKE	392	MACKEREL, JACK	13
PIKE	390	SNOOK	13
LOBSTER, SPINY	350	TILEFISH	11
SMELT	328	POMPANO	10
PERCH (FRESHWATER)	268	KINGFISH	8
BLUEGILLS	265	SABLEFISH	7
BLUEFISH	236	SHARKS	3

TABLE 6

Typical Computer Run Showing Estimates of Risk for Different Categories of Oyster Eaters

OYSTER EATERS, AL=2, EL=75%

GROUP RISK
***** ****

SEX INCLUDED	LOWEST AGE	HIGHEST AGE	AGE NOT REC	NONEATERS	ADI (MCG/70KG)	TOTAL NO.
M F NR	0	100	IN	IN	72.00	1241

	CONFIDENCE (BELOW ADI)						RISK (ABOVE ADI)					
	50%	70%	90%	95%	99%	99.9%	50%	30%	10%	5%	1%	.1%
% POPULATION	99.92	99.92	99.92	99.92	99.76	99.76	0.08	0.08	0.08	0.08	0.24	0.24

SEX INCLUDED	LOWEST AGE	HIGHEST AGE	AGE NOT REC	NONEATERS	ADI (MCG/70KG)	TOTAL NO.
M F NR	0	100	IN	OUT	72.00	1241

	CONFIDENCE (BELOW ADI)						RISK (ABOVE ADI)					
	50%	70%	90%	95%	99%	99.9%	50%	30%	10%	5%	1%	.1%
% POPULATION	99.92	99.92	99.92	99.92	99.76	99.76	0.08	0.08	0.08	0.08	0.24	0.24

SEX INCLUDED	LOWEST AGE	HIGHEST AGE	AGE NOT REC	NONEATERS	ADI (MCG/70KG)	TOTAL NO.
M	0	10	OUT	IN	72.00	54

	CONFIDENCE (BELOW ADI)						RISK (ABOVE ADI)					
	50%	70%	90%	95%	99%	99.9%	50%	30%	10%	5%	1%	.1%
% POPULATION	100.00	100.00	100.00	100.00	100.00	100.00	0.	0.	0.	0.	0.	0.

SEX INCLUDED	LOWEST AGE	HIGHEST AGE	AGE NOT REC	NONEATERS	ADI (MCG/70KG)	TOTAL NO.
F	11	17	OUT	IN	72.00	48

	CONFIDENCE (BELOW ADI)						RISK (ABOVE ADI)					
	50%	70%	90%	95%	99%	99.9%	50%	30%	10%	5%	1%	.1%
% POPULATION	100.00	100.00	100.00	100.00	100.00	100.00	0.	0.	0.	0.	0.	0.

SEX INCLUDED	LOWEST AGE	HIGHEST AGE	AGE NOT REC	NONEATERS	ADI (MCG/70KG)	TOTAL NO.
F	18	36	OUT	IN	72.00	146

	CONFIDENCE (BELOW ADI)						RISK (ABOVE ADI)					
	50%	70%	90%	95%	99%	99.9%	50%	30%	10%	5%	1%	.1%
% POPULATION	100.00	100.00	100.00	100.00	100.00	100.00	0.	0.	0.	0.	0.	0.

TABLE 7

Influence of Action Level and/or Enforcement Level on Computed Risk[1/]

Consumer Class	Action Level (ug/g)	Enforcement Level (%)	% Consumers at 5% Risk
All Seafood	20	100	0.02
	20	75	0.02
	2	100	0.00
	2	75	0.00
	1	100	0.00
	1	75	0.00
Finfish	20	100	0.00
	20	75	0.03
	2	100	0.00
	2	75	0.00
	1	100	0.00
	1	75	0.00
Shellfish	20	100	0.02
	20	75	0.07
	2	100	0.00
	2	75	0.01
	1	100	0.00
	1	75	0.01
Oyster	20	100	0.48
	20	75	0.48
	2	100	0.00
	2	75	0.08
	1	100	0.00
	1	75	0.08

1/ Consumption Factor = 1
Mean Factor = 1

TABLE 8

Influence of Changing Frequency of Consumption and Mean Cadmium Level on Computed Risk at Two Enforcement Levels

Consumer Class	Action Level (ug/g)	Enforcement Level (%)	Consumption Factor	Mean Factor	% Consumers at 5% Risk
Oyster	2	100	1	1	0.00
	2	100	2	1	0.40
	2	100	1	2	0.40
	2	75	1	1	0.08
	2	75	2	1	0.73
	2	75	1	2	0.48

TABLE 9

Influence of Changing Frequency of Consumption and Mean Cadmium Level on Computed Risk at Two Action Levels

Consumer Class	Action Level (ug/g)	Enforcement Level (%)	Consumption Factor	Mean Factor	% Consumers at 5% Risk
Oyster	2	75	2	1	0.73
	1	75	2	1	0.56
	2	75	1	2	0.48
	1	75	1	2	0.48

FIGURE I. CUMULATIVE DISTRIBUTION OF CADMIUM VALUES IN OYSTERS

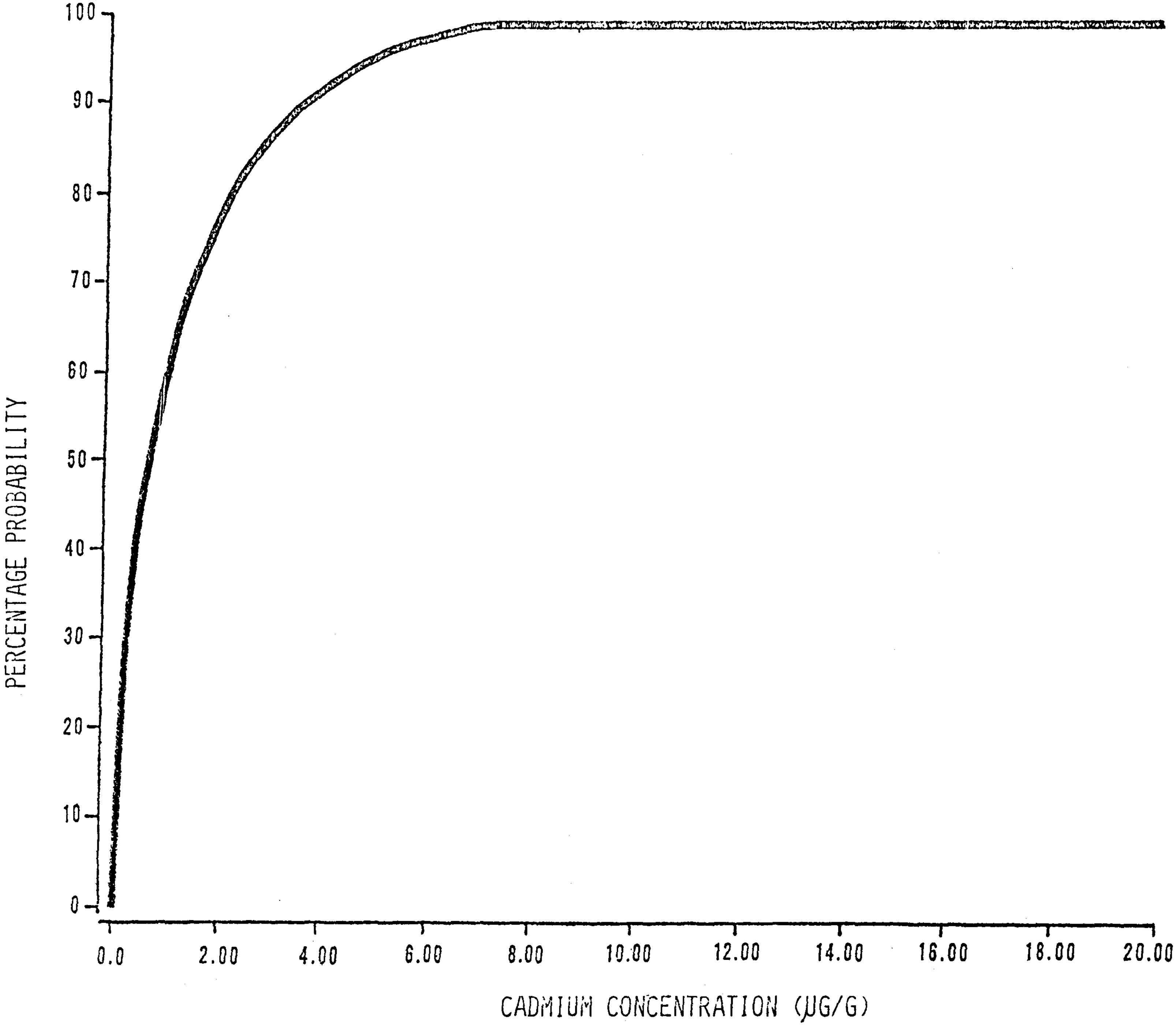

FIGURE 2

RISK ESTIMATES FOR CONSUMPTION OF CADMIUM IN SEAFOODS